Analytical method on reliability of rainfall data from X-band polarimetric radar

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Abstract. Recently in the field of disaster risk management, the applications of rainfall data from X-band Polarimetric radar are rapidly increasing due to the advancement of radar technology and analytical tools. In most cases, these rainfall data are used in the development and application of the meteorological and hydrological models. One of the typical purposes of such models is to report and disseminate disaster information such as rainfall to the government, related agencies, and the public for disaster prevention or mitigation. To accomplish this, the reliability of rainfall data from X-band Polarimetric radar is one of the most important factors as the data are the fundamental input. Equally important is the appropriate analytical method of the data to ensure the predicted rainfall information based on the collected data is reliable and safe to be used for further development and applications. Under such circumstances, this paper aim to investigate and evaluate the types of analytical methods for rainfall estimation by using X-band Polarimetric radar data. Content analysis was carried out and as a result, the statistical analyses were found as an appropriate analytical method to determine the reliability of rainfall data from the X-band Polarimetric radar. Further, the result from this study will be used to apply to a set of actual rainfall data from X-band Polarimetric radar and Automated Meteorological Data Acquisition System implemented in a region in Japan.

1. Introduction

Rainfall-induced disasters can be triggered by heavily poured and prolonged rainfall. Preventive action against disaster can be planned if heavily poured and prolonged rainfalls can be predicted accurately. Current technology using X-band Polarimetric radar for now forecasting to predict an intense and prolonged rainfall. An X-band Polarimetric radar is a combination of X-band radar technology and polarimetric analytical method. This latest radar system is very useful in short-range area observation such as in regional urban areas [1-3]. In disaster risk management studies, the applications of X-band Polarimetric radar data for meteorological and hydrological studies are growing due to the capabilities of the weather radar to provide disaster information such as details on spatial rainfall data and information for the small area [1, 3, 4]. The advantages and competences of X-band Polarimetric radar have been reviewed by many researchers [5-9] as well as its implementation in disaster preparedness and prevention activities [8, 10, 11].

There are many types of disaster studies that are based on rainfall data from X-band Polarimetric radar for further development of hydrological models and applications such as the debris flow analysis [10-12], and flood forecasting and urban flash flood studies [1, 3, 7]. The dissemination of disaster information such as rainfall intensity in real time is crucial for the government and related agencies to take actions in advance in preventing a disaster. This information is also helpful for the public, especially those who are in disaster-

prone areas. One way to help the related agencies to spread the disaster information is by using the information systems application such as web-based applications [13, 14]. Nevertheless, the reliability of rainfall data from X-band Polarimetric radar as the fundamental data input the information system application is crucial. This is to avoid the inconsistency and uncertainty of data that are to be used for further development applications in the disaster risk management field. Reliability of the data needs to be ensured as the different application requires different standard also to check the reliability of equipment which provides the data [15]. Due to that, in the disaster risk management field, the rainfall data become an important element since the data come from various sources such as weather radar, tipping bucket, disdrometer, and many others. Therefore, this paper investigates the types of analytical methods for the reliability of rainfall data from X-band Polarimetric radar, whereby the actual rainfall data will be used for further development of information systems that are currently being developed at Disaster Preparedness and Prevention Center (DPPC), UTM Kuala Lumpur.

This paper is organized as follows; Section 2 presents the analytical method used in this study, Section 3 discusses the results obtained, and Section 4 summarizes the conclusion.

2. Method and Analysis

Content Analysis Technique (CAT) was carried out for collecting and reviewing the analytical method for rainfall data from the X-band Polarimetric radar and the ground observation data. By using several keywords such as 'X-band MP', 'rainfall estimation', 'rainfall reliability', 'X-band MP data' and 'analysis method' in the searching activities and yielded 25 papers. However, only five papers are selected according to several focuses or focal points. The focal points of the investigation were on;

i. The rainfall data must be collected from X-band Polarimetric radar technology.
ii. The collected data are used for rainfall estimation and hydrological models or applications in disaster risk management.
iii. The analytical method is applied to determine the reliability and precision of rainfall data which includes the technique they have used.

The five steps conducted in the study and description of each step are summarized in Table 1. Details of each step are described in the following sections.

Table 1. The Methodology

Steps	Descriptions	Outcome
Step 1: Investigate the source of rainfall data	Collection of papers from Scopus are collected with help the Google Scholar as searching tools.	Number of papers that presented the rainfall data from X-Band Polarimetric radar and other observation tools /technology used for the analyzing purpose.
Step 2: Recognize types of disaster	Reviewed the related papers.	Types of disaster or hydrological application development that use rainfall data from X-Band Polarimetric radar and other observation tools /technology (Table 2).
Step 3: Recognize the analysis method used	Reviewed on the analysis method used to check the reliability of rainfall data.	Types of analysis method (Table 3).
Step 4: Investigates the technique used in the analysis method	Reviewed the process or technique used	List of technique from the analysis method (Table 3).

Step 5: Proposed the appropriate analysis method	Comparison and discussion on the identified analysis method	Discussion and Conclusion section.

2.1. Step 1: Investigate the source of rainfall data

The contents of the collected papers were reviewed based on the concentration pointed above and five paper has been selected. In the review process, the main source of rainfall data must come from X-band Polarimetric radar whereby this is the main issue to check the persistence of X-band Polarimetric radar for the rainfall estimation. For the ground observation data, the rainfall data come from the rain gauges and disdrometer also all the rainfall data are collected nearby with the operational X-band Polarimetric radar. Some studies are based on conventional radars such as C-band radar and NEXRAD radar for the analyzing purpose.

2.2. Step 2: Recognize types of disaster

From the concentration point, it is important to know the types of disaster happened from the research studies. By knowing the types of disaster, it is explained the potential for the development of hydrological model or application that need the rainfall data to be used. Table 2 below presents the number of studies that used rainfall data from X-band Polarimetric radar and other observation tools/technology as well as the types of disaster.

Table 2. The types observation tools/technology and disasters that used rainfall data as data input.

Observation Tool/Technology	Types of Disaster	Location	Source
XMP vs C-band	Flood	Tokyo, Japan	Maki, Maesaka [16]
XMP vs Rain Gauge	Flood and Debris Flows	Tokyo, Japan	Yonese, Kawamura [4]
XMP vs Rain Gauge XMP vs Disdrometer	Flood	Tokyo, Japan	Kim and Maki [17]
XMP vs Rain Gauge and NEXRAD	Rainfall estimation in rainstorm event	USA	Newkirk [18]
XMP vs Rain Gauge	Debris Flows	Merapi, Indonesia	Syarifuddin, Oishi [12]

*XMP – X-band Polarimetric radar

2.3. Step 3: Recognize the analysis method used

While reviewing the contents of the papers, the analytical methods for the rainfall data from X-band MP radar were recognized. The five papers have used the Statistical Analysis methods to determine the reliability of rainfall data. Table 3 below shows the analytical methods from the five papers.

Table 3. Types of analytical methods and techniques used.

Analysis Method	**Technique**	**Source**
Statistical Analysis	-	Yonese, Kawamura [4], Maki, Maesaka [16]
Statistical Analysis	Correlation & Regression	Kim and Maki [17], Maki, et al. [16]
Statistical Analysis	Correlation & Regression	Newkirk [18]

Statistical Analysis	Regression (Least Square Mean)	Syarifuddin, Oishi [12]

2.4. Step 4: Investigates the technique used in the analytical method

Four from the five papers in Table 3 above did mention the technique used in the Statistical analysis method for them to check the reliability of X-band Polarimetric radar data. One of them is Syarifuddin, Oishi [12] who used the Least Square Mean technique by comparing the hourly rainfall data from X-band Polarimetric radar and rain gauge that are located near the volcanic area, Mt. Merapi in Indonesia. The rainfall data were collected in May and September 2016, but the rainfall data between June to August were unavailable due to the electricity problem. Further, the analyzed rainfall data then were used for the development of the run-off and debris flow model. Meanwhile, Newkirk [18] used the Correlation and Regression technique to check the consistency of rainfall data provided. They intended was to see which weather radar is suitable to be used for the accumulation of rainfall data during the rainstorm events that happened in the USA. Rainfall data from NEXRAD weather radar and X-band Polarimetric radar were compared with the rain gauges to ensure the reliability of rainfall data collected. From their study, the X-band Polarimetric radar can provide more accurate rainfall data for rainfall estimations compared to NEXRAD radar, especially in the area which is prone to flood. This Correlation and Regression technique has also been applied by Maki, Maesaka [16] and Kim and Maki [17], whereby, hourly rainfall data provided by the composite of X-band Polarimetric radar were used to develop the composite rain map by X-band Polarimetric radar data with supplementary of C-band radar data in Japan.

2.5. Step 5: Proposed the appropriate analytical method

From Table 3 above, it is apparent that a Statistical Analysis has been used by most of the researchers to check the reliability of the data. However, in Statistical Analysis, there are many techniques that can be applied according to the study case and objective. Details on the result of this paper on Statistical Analysis is discussed in the following section.

3. Discussion & Conclusion

From the investigation in the previous section, the Statistical Analysis is the analytical method that is used to check the reliability of rainfall data provided by X-band Polarimetric radar. As a result of the previous research works, it has been widely agreed that X-band Polarimetric radar provides more accurate rainfall information compared to conventional weather radars and rain gauges, especially for real time data [16, 19]. For example, Kato, Maki [19] claimed that, through this Statistical Analysis method for 20 precipitation events, it was shown that the Quantitative Precipitation Estimation (QPE) from X-NET (X-band Polarimetric Network in Japan) based on the rainfall data from X-band Polarimetric radar is better or equal than the operational C- band radars based on gauge-adjusted Z-R relationship.

In Statistical Analysis method, to evaluate the reliability of rainfall data from different tools or technology, most of the researchers in disaster research area used Correlation and Regression analysis technique such as Syarifuddin, Oishi [12], Newkirk [18], Kim and Maki [17] and many others. The Correlation technique is used to evaluate the relation or dependency between two quantitative variables, while the Regression technique is used to understand and describe the nature of the relationship between variables that is, positive or negative, linear or nonlinear. Meanwhile, Least Square Means (LSM) is the system to produce an equation in Regression analysis. In the case of X-band Polarimetric radar, the rainfall data are collected in time series; where the time is the independent variable of the analysis while the amount of rainfall is the dependent variable. Therefore, by using both techniques in Statistical Analysis, it is possible to evaluate the reliability of rainfall data from X-band Polarimetric radar as mentioned by Crowder [15], to avoid the vague of information, it is needed the dependability of the resources. Moreover, this method has been widely used by many fields of research because it supports the effective presentation of the data, critical analysis of the information, and to summarize a large set of data into a simple form using the frequency distribution and graph [20].

Further, through the result from this study, the rainfall data from X-band Polarimetric radar collected in Japan will be analyzed together with the Automated Meteorological Data Acquisition System (AMeDAS) data provided by Japan Meteorology Agency (JMA), Japan. Hourly data from both sources will be analyzed by using Correlation and Regression technique.

References

[1] Chandrasekar V, Chen H, Maki M, editors. Urban flash flood applications of high-resolution rainfall estimation by X-band dual-polarization radar network. Proc SPIE 8523 Remote Sensing of the Atmosphere, Clouds, and Precipitation IV; 2012 8 November 2012; Kyoto, Japan.

[2] Einfalt T, Arnbjerg-Nielsen K, Golz C, Jensen N-E, Quirmbach M, Vaes G, et al. Towards a roadmap for use of radar rainfall data in urban drainage. *Journal of Hydrology*. 2004; **299** (3):186-202.

[3] Yoon S-S, Nakakita E. Application of an X-Band Multiparameter Radar Network for Rain-Based Urban Flood Forecasting. *Journal of Hydrologic Engineering*. 2015; **22** (5).

[4] Yonese Y, Kawamura A, Amaguchi H, Tonotsuka A. Study on the precision of 1-minute X-Band MP radar rainfall data in a small urban watershed. *International Journal of Sustainable Development and Planning*. 2018; **13** (4):614-25.

[5] NIED. Rainfall Observation by X-Band Multi-Parameter Radar. Ibaraki, Japan: National Research Institute for Earth Science and Disaster Prevention; 2005 March 2005.

[6] Kato A, Maki M. Localized Heavy Rainfall Near Zoshigaya, Tokyo, Japan on 5 August 2008 Observed by X-band Polarimetric Radar-Preliminary Analysis-. *Scientific Online Letters on the Atmosphere (SOLA)*. 2009; **5**: 89-92.

[7] Anagnostou MN, Kalogiros J, Anagnostou EN, Tarolli M, Papadopoulos A, Borga M. Performance evaluation of high-resolution rainfall estimation by X-band dual-polarization radar for flash flood applications in mountainous basins. *Journal of hydrology*. 2010; **394**(1):4-16.

[8] Hasan NA, Goto M, Miyamoto K. A review of weather radar system for rainfall induced disaster preparedness. *Int J Innov Technol Explor Eng*. 2019; **8**(7):268-77.

[9] Matrosov SY, Clark KA, Martner BE, Tokay A. X-band polarimetric radar measurements of rainfall.*Journal of Applied Meteorology*. 2002; **41**(9):941-52.

[10] Nishio M, Mori M. Analysis Of Debris Flow Disaster Due To Heavy Rain By X-Band MP Radar Data The International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences Prague, Czech Republic 2016.

[11] Ratih Indri Hapsari, Gerard Aponno, Rosa Andrie Asmara, Oishi S. Rainfall Information System Based on Weather Radar for Debris Flow Disaster Mitigation. *International Journal of Engineering & Technology*. 2018; **7** (4.44):165-71.

[12] Syarifuddin M, Oishi S, Legono D, Hapsari RI, Iguchi M. Integrating X-MP radar data to estimate rainfall induced debris flow in the Merapi volcanic area. *Advances in water resources*. 2017; **110**:249-62.

[13] Ribeiro A, Cardoso A, Marques AS, Simões NE, editors. Web-based platform for river flood monitoring 2017 4th Experiment@International Conference (expat'17) 2017; Faro, Portugal Institute of Electrical and Electronics Engineers Inc.

[14] Hasan NA, Goto M, Miyamoto K. The web-based framework of X-band polarimetric radar system. *International Journal of Recent Technology and Engineering*. 2019; **8**(2):4165-9.

[15] Crowder MJ. *Statistical analysis of reliability data*: Routledge; 2017.

[16] Maki M, Maesaka T, Kato A, Kim D, Iwanami K. Developing a composite rainfall map based on observations from an X-band polarimetric radar network and conventional C-band radar. *Indian Journal of Radio & Space Physics* 2012; **41** 461-70.

[17] Kim DS, Maki M. Validation of composite polarimetric parameters and rainfall rates from an X-band dual-polarization radar network in the Tokyo metropolitan area. *Hydrological Research Letters*. 2012; **6**:76-81.

[18] Newkirk BE. Rainfall Estimation from X-band Polarimetric Radar and Disdrometer Observation Measurements Compared to NEXRAD Measurements: An Application of Rainfall Estimates [Meterology Senior Thesis]. USA: Iowa State University 2016.
[19] Kato A, Maki M, Iwanami K, Misumi R, Maesaka T. Quantitative precipitation estimate by complementary application of X-band polarimetric radar and C-band conventional radar. *Wather Radar and Hydrology*. 2012; **351**:169-75.
[20] Saleem I, Aslam M, Azam M. The use of Statistical Methods in Mechanical Engineering. *Research Journal of Applied Sciences, Engineering and Technology*. 2013; **5**(7):2327-31.